Chapter 11
Planning, Execution, Cost Estimating, and Contracting Photogrammetric Mapping Projects

11-1. General

This chapter presents an overview of the planning, execution, and cost estimation required for a photogrammetric mapping project. Each project, because it has unique characteristics, requires careful study and planning to assure that effective methods, techniques, equipment, and personnel are employed to provide a low-risk, cost-effective solution. A professional photogrammetrist should be used in designing and prescribing photogrammetric operations. Details on standards, QC, and operational guidance are found in the respective chapters of this manual. Procedures for preparing detailed cost estimates are contained in Appendix C. All contract actions discussed in this chapter assume PL 92-582 (i.e., Brooks Act) qualification-based selection procedures were employed in obtaining the photogrammetric mapping contractor.

11-2. Project Planning

There are three aspects to project planning: planning by the Government in preparation of solicitation or delivery order issuance, planning by the contractor in preparation of the response, and planning between contractor and Government upon award of contract or issuance of a delivery order. To be effective in the planning and organization of a mapping project, the contracted photogrammetrist must become familiar with the specific needs and requirements for the project. This detail should have been fully described in the contract or delivery order scope of work, and should convey critical items such as the target map scale (i.e., horizontal accuracy), the CI (i.e., vertical accuracy), map details required, the need for ground control and its location for future use, specific engineering and construction applications intended (including critical utility locations), ground survey or verification requirements, the final products and their style and format, and the time schedule for the completion of the various phases of the work. The contracted photogrammetrist must decide that the needs and requirements of USACE can be met through the use of photogrammetric procedures and to what extent conventional topographic surveying must be employed, what equipment and personnel are needed to do the work, and what is a realistic estimate of time and cost to complete the project.

a. Risk assessment. One of the principal objectives of planning is the assessment of risk that may be inherent in the project. There are several types of risk: programmatic, technical, schedule, and cost. Risks should be identified whenever possible and the plan should include actions to mitigate their possible impact.

b. Determination of map target scale and accuracies. The most critical planning phase involves the Government's determination of the required target scale and related horizontal (planimetric feature) and vertical relief accuracies. The target scale is determined by the engineering or planning application of the map or data base product (GIS, LIS, AM/FM, etc.). The cost of mapping will vary exponentially with the selected target scale and required vertical relief accuracy, since these two factors will determine the flying height, and thus, subsequent photo coverage, model setups, etc. Therefore, it is essential that the USACE project manager exercise solid engineering judgment in arriving at the optimal map scale for the project.

(1) The map target scale, required CI, and general accuracy standard are established according to intended usage. Table 2-4 offers guidance for selecting map scales and CI's, including related survey control requirements. The nominal values shown in this table have been found to be of use in support of most USACE civil and military engineering, planning, and real estate activities.

(2) The horizontal and vertical accuracy requirements of a map or spatial data base must be commensurate with one another since the maximum flying height will be governed by that factor which is limiting. This is clearly exhibited by the negative scale and flight altitude criteria in Tables 2-8 and 2-9. Having an inordinate disparity between horizontal target scale and vertical CI (e.g., 0.5-ft contours at a 400-ft/in. target scale) can significantly drive up the cost of the map product, and may require two different flight altitudes to accommodate each parameter.

(3) Accuracy requirements, as is true for control surveys, have a great impact on cost. They define the methods and equipment that must be used. Applications requiring the highest accuracy include route location design, site development, facility location design, and determination of pay quantities. Applications requiring

lesser accuracy include regional planning studies, reconnaissance surveys, route location studies, and facility planning studies. The least amount of accuracy is required on some GIS data elements (Table 2-4). The highest intended use must govern the selected accuracy because lower accuracy applications can always make use of higher accuracy maps. However, the reverse is not true; a map that does not meet the required accuracy for a given application cannot be used for that application. The accuracy of a map (and the data used in producing the map) cannot, in general, be efficiently increased. Thus, during the planning process, consideration should be given to the "highest and best" use to which the map will be put. At times it may be advantageous to collect part of the data at a higher accuracy in anticipation of future uses. Terrain cover, such as dense forest, will make meeting accuracy requirements for contours through aerial photogrammetric methods practically impossible. More expensive transit, plane table, or terrestrial photogrammetric methods will need to be employed.

(4) Present practice indicates that maps be produced in the non-SI system of measure. However, if a map is to be made to the metric (SI) system, as may be required for military operations or projects outside the continental United States (OCONUS), it is recommended that the scale take advantage of the decimal nature of the system. Table 11-1 gives typical relationships between non-SI and SI map scales.

Table 11-1
Non-SI/SI Map Scale Relationships

Non-SI Scale	Comparable SI Scale
1:240	1:250
1:480	1:500
1:960	1:1000
1:1200	1:1000
1:2400	1:2500
1:4800	1:5000

c. Sample photo and map target scale applications. Figures 11-1 through 11-8 are intended to supplement the guidance provided in Table 2-4. They may be used as an aid in selecting optimum photo negative scales and map target scales based on specific engineering and planning applications. Figures 11-1 through Figure 11-7 depict typical planning, engineering, and real estate mapping applications, showing a portion of the manuscript (digital data base) at various target scales. The aerial negatives in Figure 11-8 show the varying detail available at different flying heights. The guidance provided in (1) - (11) corresponds to the limiting criteria given in Chapter 2. Recommended target scales and CI's are based on Class 1 mapping using an analytical plotter.

(1) Figure 11-8a

Negative Scale	1:2,000, 1 in. = 166.6 ft
Altitude above ground level (AGL)	1,000 ft
Optimum Target Scale	1 in. = 20 ft
Optimum CI	0.5 ft

Use: Extremely detailed site plan mapping for facility/structure design, detailed utility mapping for relocation, etc., where accuracy, relief, and feature detailing are critical.

(2) Figure 11-8b

Negative Scale	1:2,400, 1 in. = 200 ft
Altitude AGL	1,200 ft
Optimum Target Scale	1 in. = 30 ft
Optimum CI	1 ft

Use: Same as above, except 1-ft CI; 0.5-ft CI for lower map classes.

(3) Figure 11-8c

Negative Scale	1:3,000, 1 in. = 250 ft
Altitude AGL	1,500 ft
Optimum Target Scale	1 in. = 40 ft
Optimum CI	1 ft

Use: Standard 40-scale site plan mapping.

(4) Figure 11-8d

Negative Scale	1:3,600, 1 in. = 300 ft
Altitude AGL	1,800 ft
Optimum Target Scale	1 in. = 40 to 50 ft
Optimum CI	1 ft

Use: Standard 50-scale site plan mapping; facility structure and utility detailing for operations and maintenance or AM/FM applications; 1 in. = 50 ft air photo plans.

(5) Figure 11-e

Negative Scale (Nominal)	1:4,800, 1 in. = 400 ft
Altitude AGL	2,400 ft
Optimum Target Scale	1 in. = 60 ft
Optimum CI	1 to 2 ft

Use: Standard 60-scale site plan mapping; 1-ft contour drainage mapping for 1 in. = 200 ft scale areas; base for 1 in. = 100 ft air photo plan sheets.

(6) Figure 11-8f

Negative Scale	1:6,000, 1 in. = 500 ft
Altitude AGL	3,000 ft
Optimum Target Scale	1 in. = 80 to 100 ft
Optimum CI	2 ft

Use: Typical 1 in. = 100 ft scale mapping for design applications, grading and excavating plans, real estate, etc.

(7) Figure 11-8g

Negative Scale	1:7,200, 1 in. = 600 ft
Altitude AGL	3,600 ft
Optimum Target Scale	1 in. = 100 ft
Optimum CI	4 ft

Use: Target 4-ft contour applications, 100-scale planimetric mapping, selected utility features, planning maps (AM/FM), 1 in. = 100 ft air photo plan sheets.

(8) Figure 11-8h

Negative Scale	1:12,000, 1 in. = 1,000 ft
Altitude AGL	6,000 ft
Optimum Target Scale	1 in. = 150 to 200 ft
Optimum CI	4 to 5 ft

Use: 5-ft CI and 1 in. = 200 ft scale mapping, major surface utility features, 1 in. = 200 ft air photo plan sheets.

(9) Figure 11-8i

Negative Scale	1:14,400, 1 in. = 1,200 ft
Altitude AGL	7,200 ft
Optimum Target Scale	1 in. = 200 ft
Optimum CI	4 to 5 ft (1 m)

Use: Standard 1 in. = 200 ft general planning maps, with either 5-ft or 1-m CI, 1 in. = 200 ft air photo plan sheets.

(10) Figure 11-8j

Negative Scale	1:20,000, 1 in. = 1,666 ft
Altitude AGL	10,000 ft
Optimum Target Scale	1 in. = 300 to 400 ft
Optimum CI	5 ft

Use: Scale match to 1:20,000 scale OCONUS quads, 1 in. = 400 ft line maps or air photo plans.

(11) Figure 11-8k

Negative Scale	1:24,000, 1 in. = 2,000 ft
Altitude AGL	12,000 ft
Optimum Target Scale	1 in. = 200 ft
Optimum CI	10 ft

Use: Scale match to 1:24,000 USGS quad, small-scale (1 in. = 400 ft to 1 in. = 1,000 ft) photo screens, planimetry for general transportation corridors, creation of regional large-area GIS data bases, 1 in. = 1,000 or 2,000 ft scale air photo plan drawings.

d. Plan subelements. The overall photogrammetric mapping project plan can be subdivided into eight sub-elements that are performed primarily by the contracted professional photogrammetrist:

(1) Identification of project area, data requirements, and map scale. During the initial planning discussions with the functional map user, the target map scale and related accuracy (and flying height) requirements are determined, using the above guidance and that in Chapter 2. When the contract scope of work is prepared, the project boundaries for both aerial photography and mapping should be clearly marked on the most current available map. Once the needs and requirements of a project are delineated (during or after contract award), a detailed operation plan should be prepared by the contracted photogrammetrist. This plan should be developed to best use the equipment, personnel, and facilities that are available and the basic knowledge, experience, and professional judgment of the photogrammetrist. Some operations may be best done in-house by the contractor; others are best performed by subcontractors who have a demonstrated competence in equipment, knowledge, and experience, and who use qualified professional managers. The Operation Plan must meet the specifications and provide surveys and maps at a fair and reasonable cost to the map user. Many elements of the work depend on the project. Decisions regarding the amount and location of ground control, the use of bridging or analytical methods for control extension, the stereoplotting instruments to be used, and personnel to be assigned to the various phases of the work are critical; and each operation must be planned carefully. During the actual work on a project, each segment should be monitored as part of the contractor's QC effort; and when unforeseen events occur, the operation plan must be amended to meet such contingencies without a sacrifice of map quality and, it is hoped, without substantial additional costs.

(2) Collection of source material. Source material refers to the existing (extant) data that can be used to support the project. In order to review the physical conditions of the location to be mapped, the best available maps and/or recent photographs of the area should be obtained. The USGS quadrangle maps, which cover almost all of the United States, are invaluable for

preliminary planning and review. Sources of pre-existing horizontal and vertical control should be sought from Federal, state, and private agencies unless project control was provided by the USACE Command. Whenever possible, a site visit should be made to the area, particularly when large-scale mapping is requested that may be used for subsequent utility relocation, grading and excavation, building siting or renovation, or any other like project where potential errors or omission can be critical during construction. Material from any adjoining (abutting) projects, either completed or in progress, should be used.

(3) Development of specifications. As definitive and clear a set of specifications as possible should be prepared for the project through the joint efforts of the functional map user and the USACE COR in charge of the mapping phase of the project. The specifications should attempt to minimize the likelihood of misunderstanding of the requirements by the contractor. Because the USACE COR cannot maintain constant supervision over photogrammetric operations, he must rely upon the integrity and reliability of the professional photogrammetrists employed on the project. Regardless, well thought out and written specifications will minimize the risk of misinterpretation. The most successful mapping projects are those accomplished when specifications are prepared for the specific project at hand, and there is a clear understanding of the requirements and specifications between USACE and the contractor.

(4) Flight map design. Flight maps are best prepared by the contractor, not the Government specification writer. The map on which the flight lines are drawn should be the best available map of the project area. USGS quadrangle maps at scales of 1:24,000 or 1:62,500 are particularly valuable for this purpose. Previously flown aerial photographs can be used especially when reflights of this photography are ordered. In general, it is best to plan flight lines parallel to the longest dimension of the project area. For areas having irregular boundaries or for meandering streams, block flying, that is, two or more parallel flight lines to cover the area, is preferable to having many short lines whose directions follow the irregular directions of the area. Also, consideration should be given to roads and trails adjacent to the project area. Incorporating these access routes into the photography frequently will facilitate the necessary ground surveys for photo control. Flight lines must recognize potential flight hazards. For example, lines should be parallel to the ridge lines of mountains rather than leading into them. The scale of the photograph should be determined by the focal length of the camera to be used and by the CI of the topographic maps. In remote and inaccessible areas, additional consideration should be given to existing horizontal and vertical control, and to places within or adjacent to the mapping area where photo control points may be found. Unusual conditions may dictate special (usually higher altitude photography) flights be flown.

(5) Project equipment and materials requirements. Specifications should be prepared to dictate the use of certain equipment, materials, and technical procedures and to stipulate the meeting of certain accuracy limits. The type of camera, focal length, film emulsion type, etc., must be specified. However, the type of field or compilation equipment should be specified only if absolutely necessary to assure proper performance. Maximum use of existing USACE guide specifications and references to the criteria in this manual should be made.

(6) Methodology and equipment. Photogrammetric firms are, in accordance with PL 92-582 qualification-based procedures, selected upon the basis of their professional reputation, their equipment, personnel, and demonstrated technical ability to perform a specific project or phase of photogrammetric work. Unless there is an overriding need, the contractor should not be required to adopt particular production methods. However, if specific methods are required to meet accuracy, deliverables, or other requirements, they should be spelled out and made part of the contract. Table 11-2 provides guidance as to which mapping techniques are appropriate for each of the three map classes.

(7) Schedule. A schedule for the completion of the various phases of the project should be prepared. The complexity of this schedule will obviously vary with the scope of the work. A bar chart showing time along the top and work breakdown along the left side (Figure 11-9) is extremely helpful during early planning stages to assure a realistic schedule. For more detailed planning, the critical path method is more informative for determining the earliest and latest start dates of the various phases and for defining the set of operations that are time-critical (critical path) in meeting the schedule. Unanticipated delays in the critical path will cause delay in the overall schedule and may have unfavorable cost impacts. It is recommended that any one of a number of desktop computer software packages be purchased to aid in the production of these charts. For extensive, long-term mapping projects (i.e., full photo coverage on an entire state or region), the Government may require periodic submittals of these progress schedules.

Table 11-2
Allowable Photo Mapping Techniques

Mapping Technique	Accuracy Classification: Class 1	Class 2	Class 3
Direct Digital Data by Stereoplotter from Overlapping 9x9 Aerial Photos	Horizontal and Vertical	Horizontal and Vertical	Horizontal and Vertical
Digitizing Maps Made by Stereoplotter from Overlapping 9x9 Aerial Photos	Horizontal and Vertical	Horizontal and Vertical	Horizontal and Vertical
Digitizing/Scaling Orthophotographs	Horizontal Only	Horizontal Only	Horizontal Only
Digitizing/Scaling Orthophotographs with Superimposed Contours/Elevations	Horizontal and Vertical	Horizontal and Vertical	Horizontal and Vertical
Digitizing/Scaling Controlled Mosaics	Not Allowed	Not Allowed	Horizontal Only
Digitizing/Scaling Landsat Imagery	Not Allowed	Not Allowed	Horizontal Only
Digitizing/Scaling SPOT Imagery	Not Allowed	Not Allowed	Horizontal Only
Digitizing/Scaling Maps made by Transferscopes from 9x9 photos	Not Allowed	Not Allowed	Horizontal Only
Digitizing/Scaling Enlarged Aerial Plan Sheets	Not Allowed	Not Allowed	Horizontal Only

(8) Deliverables. A precise list of deliverables should be clearly identified in the contract. Each of the deliverables must be adequately defined and the applicable standards and specifications identified. A submittal schedule must also be developed.

11-3. Photography

This phase consists of developing a detailed flight plan, flying and photography, developing the negatives, and producing contact prints and diapositives.

a. Detailed flight plan. Flight maps should be prepared by the contracted photogrammetric engineer to provide instructions to the flight crew on the location and position of the flight lines, the overlap between successive photographs, the location of adjacent flight lines, the side lap between flight lines, and the camera and film to be used. Special instructions include conditions to be observed, such as when the photographs are to be taken, i.e. when the ground is free of snow, or when the leaves are off the trees, or "photograph between the hours of .... and ....," or "photographs of the ....Bay are to be taken at high tide," etc.

b. Flying for photographic collection. An air crew experienced in photographic collection for photogrammetric mapping is essential. The crew must be aware of the need to conform to flight design and must have the ability to do so. The aircraft should be appropriate for the specific project and must conform to Federal Aviation Administration (FAA) regulations. The modifications made to accommodate the aerial camera must be FAA approved.

c. Film processing and inspection. Film must be processed in conformance with the standards and specifications written in the contract, or as referenced to this manual from the contract. Care is required to meet the required density values. Film must be handled to minimize scratches, marks, discoloration, and dimensional instability. Annotations should be placed on each frame.

d. Contact prints and diapositives. Contact prints and diapositives must be free of scratches, marks, and discolorations, and otherwise conform to standards set forth in the contract. Diapositives are required to be dimensionally stable.

e. Photo indexes, air photo plan enlargements, mosaics, orthophotographs. The accuracy of these photographic products depends upon their intended use. Orthophotographs may be map "substitutes" and therefore warrant sufficient care in production to meet map accuracy requirements. Mosaics and air photo plan sheets may be controlled, semicontrolled, or uncontrolled, depending upon requirements.

11-4. Ground Control and Targeting Requirements

Accurate, well-distributed, photoidentifiable control points are essential for a successful project.

a. Preparation. In preparing for the control survey for a photogrammetric mapping project, the accuracy and reliability of the existing survey data should be ascertained.

b. Photo control. Photo control points are points on the ground whose images can be identified on the aerial photographs to be used for photogrammetric mapping. Based upon the photo control requirements, some photo control points will require horizontal (X-Y) coordinates, others will need elevations only, and some will require both horizontal and vertical values. The identification of the photo control points on the aerial photographs is critical. Extreme care must be exercised by the contractor's surveyor to make certain of this identification. The surveyor should examine the photo control point in the field using a small pocket stereoscope with the aerial photographs. Once a photo control point is identified, its position on the photograph should be pricked using a sharp needle. A brief description and sketch of each point should be made on the reverse side (without photo images) of the photograph. The photographs used in the field provide the means of communication between the surveyor and the photogrammetrist who will be using the survey data in mapping. If the surveyor can see clearly the points that he has selected in his stereoscope, it is almost certain that the photogrammetrist in the office will be certain of the point. Good photo control points include relatively flat areas at the intersection of fence lines, sidewalk corners, prominent road markings or spots, etc. Road center-line intersections are poor for horizontal points, but if the area is reasonably flat, they may be good for vertical points. Points on steep slopes are poor.

c. Targeting. While most photo control points are selected after the photographs have been made, there are times when marking points on the ground prior to obtaining the photographs is advantageous. Premarking or panelling points is particularly valuable when bridging and analytical aerotriangulation methods are to be used in the mapping process. Panels are made using colored fabric (unbleached muslin), plastic, or in some instances, paint on roads. The color to be used should be in sharp contrast to the background area, i.e., black on a white background, etc. Panels are in the form of crosses, T's, or V's. The long dimension of the panel should be a minimum of 0.01 of the negative scale in feet. For photographs at a scale of 1 in. = 500 ft, this would be 5 ft. The minimum width should be 0.01 of the photo scale in inches. Larger targets will be more easily visible, while anything smaller may not be seen on the photographs. The control point is located directly under the center of the cross or the intersection of the lines of the T or V. The panels should be secured to the ground. Rocks or forked sticks driven through the material do a good job.

d. Location of photo control. The location of the photo control points on the photography should be selected by the photogrammetrist, either by designation of an area in which a specific control point should be obtained or by actually identifying the point on the photograph. The former method is to be preferred since the surveyor should be required to make the most reliable selection in the field. The points are numbered to facilitate their use and further identification. For small mapping projects, or where good judgment and economy dictate, photo control should be obtained for each of the stereomodels to be used in the mapping. (A stereomodel is the area included in the overlap between two photographs.) An ideal situation requires at least three horizontal and four vertical photo control points for each stereomodel. The vertical controls should not be in a straight line. They should be in each of the four corners of the model and generally be immediately adjacent to the mapping boundaries. The horizontal control may use the same points used for vertical control or may be located along an easily accessible survey route within or just outside the mapping limits. Additional adjacent models should be controlled, using a similar configuration, making sure that traverses and bench level lines are on closed adjusted loops.

e. Ground control surveys. Ground control surveys must have sufficient accuracy to assure that the compilation will meet the contracted map accuracy. Refer to Table 2-4 for guidance on recommended base control accuracy requirements. If targeting has already been completed, the survey must include the targeted points unless they are for aerotriangulation. Any method of survey is permissible provided accuracy and other criteria are met.

f. Computation and adjustment. Survey data should be adjusted by the method of least squares or equivalent.

Any outliers (points whose residuals generally exceed three times the normalized standard error) should be analyzed and corrected. Coordinates are to be reduced to the appropriate projection and datum.

g. Control report. A control report including sketches with witnesses of the control points, statistical results of the adjustment, and geographic coordinates in the appropriate projection and datum should be furnished. A qualitative assessment of the control along with noteworthy observations should be included in this report.

11-5. Stereo Compilation and Aerotriangulation

a. Aerotriangulation. Aerotriangulation is normally a cost-effective method of extending and increasing the density of photo control. Aerotriangulation is used most successfully on relatively large mapping projects, on jobs where existing basic control is found at each end of a mapping area, or when the requirements of the job do not include the establishment of ground control points within the mapping area. When two or more adjacent flight lines are involved, a block system of aerotriangulation should be used.

b. Map compilation. The target scale, CI, map details, and the accuracy of the final map are the primary factors that drive the production and QC performance of the photogrammetric contractor. The map compilation phase of the work ties these requirements together to produce the manuscript map or equivalent spatial/digital design file. The plotting ratio (the optimum enlargement or reduction factor between the scale of the aerial photography and the plotting scale) varies with the accuracy requirements of the project. There are four relevant scale relationships to be considered: the scale of the aerial negative, the scale of the stereomodel (viewing scale), the scale of the map compilation, and the final map publication scale. Each of these scales impinges upon the final accuracy of the map.

c. Digital compilation. There are several types of DTM's: grid, cross section, remeasurement, and critical point. During the project planning phase, it must be decided what the purpose of the compilation is and then specify which type of DTM is needed. Such elements as standard point spacing, maximum point spacing, type of media, and data structure must be clearly specified in the contract or delivery order scope of work.

d. Compilation edit. Upon completion of the map compilation by the stereoplotter operator, a thorough review and edit must be made before final drafting. This element of QC is designed to check for discernible errors (unusual topographic features can be checked by examining the contact prints stereoscopically), to ensure that the manuscript map is conventional and consistent in expression, that the user's specifications have been followed (designated mapping limits, symbols, amount and type of details shown, names, format and content, etc.), that ties have been made and referenced to adjacent sheets, that control has been labeled, and that the manuscript is complete with respect to content and appearance.

11-6. Field Edit and Completion

Field inspection of manuscripts is usually necessary to fill in details required by the specifications that may have been obscured on the aerial photography or that are too small to be recognized on the photographs. For map scales of 100 ft/in. and smaller, the field edit takes the form of classification of data. This might include names of landmark buildings, highways, trails, cemeteries, identification of major features, and similar general data. Classification surveys can be made before the maps are compiled, for which it is desirable to use enlarged photographs. For maps of larger scales, particularly those larger than 100 ft/in., the field edit becomes an essential part of the mapping process. Large-scale maps are used for the design of engineering projects; and complete map details are critical, especially if structure or utility relocations are involved. In urban areas, parked cars may hide manholes and catch basins, utility poles and outlets should be checked and identified, property corners and the names of owners verified, trees and landscape plans identified, invert of first-floor elevations obtained, and such other details acquired as may be needed by the functional map. For this purpose, prints of the manuscript map should be used in the field. The field notations must be neat and legible, with any supplemental ground survey data properly recorded.

11-7. Final Drafting and Reproduction

The manuscript map is the initial medium in the preparation of the final map. In some instances, it is the final product delivered to the map user. Content and accuracy of the final maps must be in compliance with the specifications. Final sheets should be uniform in size (unless specified otherwise), format symbolization, line weights, and accuracy. To preserve the accuracy standards of the photogrammetric process, the manuscript (the original) map must be drawn on a stable base material (polyester sheets, Dupont Mylar, or equal are recommended). Experience indicates that the manuscript sheets should be cut from the manufacturer's rolls and allowed to "season" in the atmosphere of the map compilation area. If the horizontal photo control has been computed on the SPCS, this grid, or a local grid, should be plotted on the manuscript sheets. Best results are obtained by using a coordinatograph, or programmed drafting instruments. Precise grids can be laid out using a beam compass. The horizontal control points should be plotted, preferably through the use of automated plotting equipment.

11-8. Quality Control Actions

The photogrammetric mapping process entails the use of many separate operations, each of which has the possibility of introducing systematic and random errors. Each step must be carefully monitored by the contractor to ensure that allowable limits are not exceeded. The following is a summary of the QC, and Government quality assurance as applicable, needed for a reliable photogrammetric mapping project:

a. Aerial camera. Calibration certificate to check distortion, resolution, and camera configuration.

b. Original negatives. Check image quality, coverage, and forward and side overlaps. Set up random models in a stereoplotter to check for residual y-parallax.

c. Photo control. Check closures for traverses and levels. Closed loops should always be run on primary mapping control networks.

d. Stereo orientation. Review and check setup reports for each stereomodel. Investigate photo control points that are inconsistent with other points or that do not produce a "flat" model. Insist upon operator and/or field survey checks on erroneous or inconsistent control points.

e. Office edit. Experienced topographers should examine each manuscript map.

f. Field edit. Large-scale maps for critical engineering projects should be examined and, if necessary, tested in the field. Unusual topographic features or conditions should be noted, visited, and checked.

g. Drafting edit. Final sheets should be checked for accuracy of content and clarity of presentation.

11-9. Factors in Estimating Costs of Photogrammetric Projects

a. General. Cost estimation enters at two places in the project cycle:

(1) During planning (budget estimates). If the project or any part of the project is to be contracted, an estimate of the contracted phases must be made in order to budget the cost either in the current or the out years. Those parts of the project to be done by another Government agency will need to be estimated to program the amount that will need to be transferred. Those parts to be done by the agency itself will need to be estimated to forecast the in-house resources needed; at a minimum, this includes management time for the COR. Guidance for developing rough budget estimates is given in Appendix C.

(2) During proposal evaluation. Prior to contract negotiations, a detailed Independent Government Estimate (IGE) must be prepared. Appendix C contains guidance and samples of detailed IGE's for typical USACE mapping projects. One of the elements in evaluating a contractor's proposal relative to the IGE is cost realism. Unrealistically low (or high) estimates should be questioned. Often, unrealistic estimates are a result of oversight, excessive precaution, or lack of clear understanding of the contract requirements, not only by the prospective contractor but also by the preparer of the IGE. These disparities are resolved during negotiations with appropriate adjustments made to the IGE.

b. Fixed and variable costs. Project costs can be divided into fixed and variable costs. Fixed costs are those, once the project has been defined, that are incurred regardless of unforeseen contingencies and modifications. For example, the cost of moving the aircraft and crew from the home base to the project base is a fixed cost. Variable costs are those that change as contingencies change. For example, the number of days that an aircraft is grounded at the project base because of inclement weather is a variable cost.

c. Contract type. The usual contract for photogrammetric mapping projects is a firm fixed price, as derived from PL 92-582 selection and negotiation procedures. Consequently, the contractor is contractually committed to producing the deliverables for the agreed-upon price. The Government, when negotiating, should assess whether it is priced realistically.

d. Cost breakdown. A rule of thumb for estimating the breakdown of costs between the various phases of a typical urban mapping project is as follows:

(1) Aerial Photography: 5 to 10 percent

(2) Geodetic (Field) Control: 30 to 50 percent

(3) Map Production: 45 to 60 percent

e. Cost breakdown example. Table 11-3 is a cost breakdown adapted from an example in the "Manual of Photogrammetry" (American Society of Photogrammetry 1980).

Table 11-3
Example Cost Breakdown for a Photogrammetric Mapping Project

Operation	Percent of Operation
Aerial Photography	3
Geodetic (Field) Control	15
Map Production	82
Layout	3
Stereocompilation	22
Aerotriangulation	2
Model Orientation	2
Planimetry	12
Contours	6
Drafting/scribing	46
Planimetry	22
Contours	24
Editing (15 percent of Drafting)	7
Mosaics, Index Map	2
Printing	2

Note: For modern digital mapping operations, the relative percentages of stereocompilation and Drafting/Scribing can easily reverse.

f. Cost drivers. Each operation of the photogrammetric mapping project has its cost drivers, i.e., those items that have the greatest impact on the project cost. Map production, which usually contributes the greatest cost to the overall project, is the first place to look for savings; the next is geodetic control; and the last, aerial photography. Aerial photography, being generally less than 10 percent of the total project cost, offers the least potential for cost savings. Likewise, the effort spent preparing cost estimates should be proportionate to the relative costs shown in the above example. Many estimators spend more time counting the number of photographs required to cover the project (3 percent of overall cost) than in estimating stereoplotter compilation time (a 22 percent cost item).

(1) Aerial photography. Photographic scale enters into cost generally in two ways. First is its effect on the number of photographs required to cover a unit area of the terrain. Second is its effect on the required flying height and, therefore, on the type of aircraft and equipment; very high flown photography will require a more expensive aircraft. Emulsion type affects principally the developing and handling requirements. Color film requires a more expensive process than does black and white. The location of the project area and its accessibility to a project airfield is a consideration. If each day's collection requires a several-hundred-mile flight to reach the project area, considerable extra expense will be incurred. If the airspace above the project is restricted in any way, extra expense may be incurred. Naturally, the size of the project area is a consideration. Each additional flight line necessitates an additional turn of the aircraft, which adds to total "unproductive" flight time. Fewer but longer flight lines are generally preferable. Unpredictable and inhospitable weather conditions such as rain, fog, cloud cover, snow, snow cover, etc., may cause the air crew to remain at the project base for an inordinately long period of time waiting for proper flying conditions. In particularly unfortunate circumstances, the project may have to be aborted altogether for that flying season. High winds may make it impossible to meet flight design, tilt, crab, and other constraints. Mountainous terrain will have the effect of obscuring features, necessitating additional coverage to fill in the gaps.

(2) Geodetic (field) control. Terrain type and cover have a great impact on cost; mountainous and brush-choked terrain make maneuvering for the ground control party difficult. The GPS can greatly speed up the establishment of control. Placing control close to roads and trails facilitates its establishment; therefore, the density of the transportation network is critical to cost. Control should be no denser than required to meet accuracy requirements. Minimizing project-specific control through the use of preexisting control is very cost-effective. Aerotriangulation should be used, wherever possible, to densify control.

(3) Map production. The density and comprehensiveness of feature detail are perhaps the most vigorous

drivers of cost. The compilation of planimetric detail generally absorbs the greatest percentage of time during the compilation phase. Field completion, because of the travel time and per diem required, is also expensive. Nonphotographic information such as cartographic names, underground utilities, and political boundaries can be time-consuming to obtain and render.

(4) Other cost drivers. There are a number of other cost drivers that can be scrutinized. Contract direct labor rates, overhead charges, general and administrative charges, and fees should all be carefully reviewed. These are contractual matters and fall under the responsibility of the Contracting Officer. However, the assessment of the qualifications of the project personnel and of the amount and level of management and supervision, and estimates of the time required to perform each specific task should be thoroughly assessed by the technical personnel. Schedule can have a great impact on cost. If an operation can be coordinated with other ongoing projects, considerable savings may be possible. This is especially true if the project area is remote and thus is subject to high fixed costs of mobilization that may be allocated across several projects. Also, if the schedule can coincide with the "best" flying season and if overtime rates can be avoided, cost savings can be realized; priority projects generally cost more. The number and extent of briefings, meetings, and reports should be sufficient to assure proper monitoring of the performance on the project, but they should not interfere with its progress. The deliverables should be well defined, actually needed and used for Government QA checks, and not beyond the requirements of the project.

g. Industry cost terms. Below is a short description of several cost terms used by the commercial mapping industry in their cost analysis processes. These may not correspond directly to Government cost item terminology, or "seven-item breakdown," and any differences are usually resolved during the field audit process.

(1) Direct labor. Includes the labor of those operational personnel that are directly assigned to perform work on the deliverables.

(2) Overhead on direct labor. This includes fringe benefits such as vacation, holidays, sick leave, pensions, bonuses, downtime and marketing; work and office space, utilities, and equipment; and items such as pens and pencils that may be too small (de minimus) to keep accurate accounting of. Overhead is calculated as a percentage of direct labor and usually ranges from 60 percent to 175 percent depending upon the nature of the business.

(3) Other direct charges (ODC). These are nonlabor costs and include travel, per diem, and other miscellaneous special costs such as rental, lease, or purchase of computers, software, and supplies such as film obtained specifically for the contract.

(4) General and administrative overhead (G&A). This category includes salaries and fringe benefits of indirect personnel, such as officers of the company, accounting, administrative, purchasing, and contracts personnel along with their office space, utilities, equipment, and supplies. Bid and proposal and investigations, research, and development costs are allocated to G&A. G&A usually ranges from 5 percent to 25 percent of the total of direct labor, overhead, and ODC's, depending upon the nature of the business and precisely how costs are allocated between direct overhead and G&A.

(5) Fee (profit). This is an amount added to the cost of the contract as "consideration" to the business. The method of calculating fee varies depending upon the type of contract, and may not represent the actual profit received by the company (which may be higher or lower). Fee generally ranges from 5 to 15 percent and should be a function of the quality of the contractor's performance on the project and on the degree of risk assumed by the contractor. On Government contracts, profits are computed using weighted guidelines.

11-10. Contracted Photogrammetric Mapping Services

Most USACE photogrammetric mapping requirements are obtained by contract. This paragraph briefly describes the general procedures used in contracting for these services. The companion Civil Works Construction Guide Specification, CW 01335, should be consulted for specific contract formats. Appendix C to this manual provides guidance in preparing cost estimates. For detailed guidance on procurement policies and practices, refer to the appropriate procurement regulations.

11-11. PL 92-582 Qualification-Based Selection

In accordance with current laws and regulations, photogrammetric mapping and surveying services must be procured using qualification-based selection procedures in accordance with PL 92-582 (Brooks Act). These services may be included as part of a fixed-price (single-project scope) A-E design contract or included as a line item on an indefinite delivery type (IDT) surveying and mapping services contract. In some instances, a fixed-scope photo mapping contract may be issued. In almost all cases, photogrammetric mapping and related surveying services will be negotiated as part of the A-E selection process; therefore, a Government cost estimate for these services must be prepared in advance of formal negotiations with the contractor. Exceptions are noted in CW 01335.

11-12. Contract Types

Fixed-scope photo mapping service contracts are not common; in most cases, USACE Commands obtain photo mapping services via IDT contracting methods. One or more delivery orders may be placed against the IDT contract for specific projects. An overall contract threshold is established—currently $400,000 per year per contract; thus, the accumulation of individual orders cannot exceed this limit. Individual orders placed against the basic contract are normally limited to $75,000. The term of an IDT contract is usually set at 1 year; however, option year extensions may be authorized. Separate project scopes are written and negotiated for each order. The unit prices established in the basic IDT contract are used as a basis for estimating and negotiating each delivery order. The basic unit prices in an IDT contract are established as part of the A-E acquisition and negotiation process; therefore, a Government cost estimate for these services must be prepared in advance of formal negotiations with the contractor. These basic unit prices must adequately represent the anticipated work over the course of the IDT contract—typically a 1-year period. (Separate rates are negotiated for additional option years.) Deficiencies in these unit rates will impact subsequent delivery order negotiations.

11-13. Unit Price Basis

The unit prices scheduled for each scheduled photo mapping service in a contract must be estimated using the following USACE-directed detailed analysis method. The seven-item breakdown for estimating costs is given in Table 11-4. A typical contract price schedule is shown in CW 01335.

Table 11-4
Factors for Estimating Costs

Item	Description
I	Direct labor or salary costs of pilots, photo mapping technicians, etc.: includes applicable overtime or other differentials necessitated by the observing schedule.
II	Overhead on Direct Labor.
III	G&A Overhead Costs (on Direct Labor).
IV	Material Costs.[1]
V	Travel and Transportation Costs: crew travel, per diem, etc. Includes all associated costs of vehicles.[1]
VI	Other Costs: includes survey equipment and photogrammetric instrumentation. Major equipment costs should be amortized down to a daily rate, based on average utilization rates, expected life, etc. Exclude all instrumentation and plant costs covered under G&A, such as interest.[1]
VII	Profit (To be computed/negotiated on individual delivery orders per Engineer Federal Acquisition Regulation Supplement 15).

Note:
1. Government audit must confirm if any of these direct costs are included in overhead.

11-14. Verification of Contractor Cost or Pricing Data

It is essential (but not always required) that a cost analysis, price analysis, and field pricing support audit be employed to verify all cost or pricing data submitted by a contractor, in particular, for actual aircraft, instrumentation utilization rates, and reduced costs per day. Some aircraft operation and maintenance costs may be direct or portions may be indirectly included in a firm's G&A overhead account. In some instances, a firm may lease/rent aircraft, instruments, or equipment in lieu of purchase. Rental would be economically justified only on limited-scope projects and if the equipment is deployed on a full-time basis. Whether the equipment is rented or purchased, the primary (and most variable) factor is the GPS equipment's actual utilization rate, or number of actual billing days to clients over a year.

Only a detailed audit and cost analysis can establish such rates, and justify modifications to the usually rough assumptions used in the IGE. In addition, an audit will establish any nonproductive labor/costs, which are transferred to a contractor's G&A. Costs and overhead percentages are subject to considerable geographic, project, and contractor-dependent variation. Associated costs for insurance, maintenance contracts, interest, etc., are presumed to be indirectly factored into a firm's G&A overhead account. If not, then such costs must be directly added to the basic equipment depreciation rates. Other accounting methods for developing daily costs of equipment may be used. Equipment utilization estimates in an IGE must be subsequently revised (during negotiations) based on actual rates as determined from a detailed cost analysis and field price support audits.

11-15. IDT Ordering

Since unit prices have been established in the basic contract, each such delivery order is negotiated strictly for effort. The negotiated fee on a delivery order is then a straight mathematical procedure of multiplying the agreed-upon effort (time or unit of measure quantity) against the unit prices, plus an allowance for profit. Thus, an IGE is required for each order placed, along with a detailed profit computation, documented records of negotiations, etc. The scope is attached to a DD 1155 order placed against the basic contract. The process for estimating the time to perform any particular photo mapping or survey function in a given project is totally dependent upon the knowledge and personal field experience of the Government estimator. Figures 11-10 through 11-15 depict the flow of a typical ordering action for photogrammetric mapping services. These figures, furnished by the US Army Engineer District, Seattle, show the IDT contract delivery order process as a part of the Fort Lewis Master Plan. Figure 11-16 represents a Government cost estimate for in-house photogrammetric mapping services.